CMS (2008) 5:1–5
DOI 10.1007/s10287-007-0039-y

EDITORIAL

Editorial

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Published online: 22 February 2007

Preface. Energy economics and Operations Research/Management Science have a long common history. In the 1940s, two leading French economists, Marcel Boiteux and Pierre Massé destined to occupy directorial positions at the French power utility (Electricité de France, EDF), initiated the trend. Massé (1946) published a document which contained in essence the fundamental principle of dynamic programming. The problem dealt with concerned the optimal management of reservoirs for hydro-power production. Boiteux (1949a,b) studied the implementation of marginal cost pricing schemes for public utilities and Massé and Gibrat (1957) using linear programming to model electricity production management derived from the duality principle the rule of marginal cost pricing for power utilities. Manne (1958) published a seminal paper on the use of linear programming to model the operations of an oil refinery. Since then, OR/MS models have been routinely used by electricity producers and oil refineries to manage their operations and plan their development. Energy has been an important field of applications of OR/MS and of Industrial organization, the branch of economics interested in analyzing market structures. For example, computational models were developed for the oil Pindyck (1978) and natural gas Haurie et al. (1987) sectors, with the introduction of noncooperative game solutions in order to represent the oligopolistic market structure of these sectors and stochastic variational inequalities in order to compute equilibria under uncertainty Haurie et al. (1990).

Among all these developments we shall focus on a particular stream of research where detailed energy and macroeconomic models were combined to assess global energy and environmental policies. The oil crisis in 1973 triggered

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an interest in the modeling of the whole energy systems to identify new pathways toward long term sustainability of the energy system, in the perspective of a permanent oil shortage. In France again, Dominique Finon (1974) proposed the EFOM model, a comprehensive linear program representing the energy flows over a long time horizon in the whole energy system of a region. His work was rapidly followed by similar developments in USA, when Hoffman (1973), working at Brookhaven National Labs, proposed the BESOM model. At the end of the 1970s, a committee of participating countries working under the aegis of the International Energy Agency, ETSAP (Energy Technology Systems Analysis Program), launched the development of MARKAL (Fishbone and Abilock 1981) (Market Allocation). It was still a linear programming approach but with a capacity to handle the detailed description of all existing and potential (new) technologies that could enter the energy market in the next 50 years. Simultaneously, in the model PIES developed in the *Project Independence* Hogan (1974) and in the ETA-MACRO model proposed by Manne (1977a,b), the coupling of energy models with macro-economic equilibrium model started to be developed, relying on nonlinear programming methods. Also at this period, cooperative game solutions, combined with nonlinear programming methods have been used to model efficient power exchange between interconnected networks Breton et al. (1978).

Computational progresses have accompanied these modeling developments. The models of the 1970s were run on large computers developed for nuclear physics applications. Soon the development of powerful workstations and high performance optimizers allowed the analysts to run large models on personal computers. The MARKAL models were expanded to handle material and financial flows in addition to energy flows Berger et al. (1992); stochastic programming versions have been proposed to "robustify" the proposed scenarios Fragnière and Haurie (1996), Kanudia and Loulou (1998); nonlinear programming methods were implemented to compute partial or global economic equilibrium in an economy where the energy system is represented in all its technological detail (MARKAL-Macro, Manne and Wene (1994) and MARKALED, Kanudia and Loulou (1999); Kanudia and Shukla (1998)). The climate change issue and the necessity to limit greenhouse gas (GHG) emissions have given a new impetus to the development of more comprehensive models including a coupling between climate and economic dynamics. The MERGE model Manne et al. (1994) is an archetypal example of an Integrated Assessment Model (IAM) built around a single large-scale nonlinear programming formulation. Other ways of coupling different sorts of models through decomposition methods have been tested and applied with success to link together country energy models of different types (Bahn et al. 1998), or to link optimal economic growth models with climate simulation models (Beltran et al. 2005; Drouet et al. 2006).

This special issue shows the vitality of this line of research where the links between energy production models, macroeconomic general equilibrium models and climate change models are explored in computational OR/MS models. Several papers in this issue are direct extensions or applications of the

MARKAL family of models, others propose new tools to model macroeconomic interactions in the implementation of climate policies. The first two papers by Loulou and Labriet give a complete description of TIAM which is an integrated assessment model based on TIMES (the integrated MARKAL-EFOM system) which is itself the last avatar in the MARKAL family of models. This presentation of TIAM is followed by a detailed presentation by Bernard and Vielle of GEMINI-E3, a general equilibrium model designed to represent interactions between economy, energy and the environment both at international and national levels. The readers will thus find here the up-to-date models for the energy sector and for the macroeconomic interactions between energy, economy and the global environmental constraints. The two following papers use a world MARKAL model: Krzyzanowski et al. analyze the conditions for penetration of hydrogen technologies in the transport sectors and Loulou and Labriet analyze cooperation between countries in mitigating world climate, using non-cooperative and cooperative game solution concepts. The next three papers deal with macroeconomic modeling of energy-environment systems: Bauer et al. compare two approaches in the coupling of energy models with macroeconomic growth models; Bahn and Leach use an overlapping generation macroeconomic model to analyze the secondary benefits of climate mitigation; Drouet et al. formulate a noncooperative game with coupled constraints to represent the conditions of post-Kyoto negotiations on climate change and solve it via an oracle based optimization technique where the "oracle" is provided by simulation runs on GEMINI-E3. The last two papers offer different perspectives on the use of models to assess global climate change policies: Kypreos uses MERGE to produce an ensemble simulation and implement a probabilistic assessment of the effectiveness of climate policies and Scheffran represents the adaptation of the decision processes that will take place in the long term climate change management.

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1. Richard Loulou and Maryse Labriet, ETSAP-TIAM: The TIMES Integrated Assessment Model Part I: Model Structure.
2. Richard Loulou ETSAP-TIAM: The TIMES Integrated Assessment Model Part II: Mathematical Formulation.
3. Alain Bernard and Marc Vielle, *GEMINI-E3*, A General Equilibrium Model of International-National Interactions between Economy, Energy and the Environment.
4. Daniel A. Krzyzanowski, Socrates Kypreos, Leonardo Barreto, Supporting Hydrogen Based Transportation: Case Study with the Global MARKAL Model.

5. Maryse Labriet and Richard Loulou, How Crucial is Cooperation in Mitigating World Climate? Analysis with World-MARKAL.
6. Nico Bauer, Ottmar Edenhofer, Socrates Kypreos, Linking Energy System and Macroeconomic Growth Models.
7. Olivier Bahn and Andrew Leach, The Secondary Benefits of Climate Change Mitigation: An Overlapping Generations Approach.
8. Laurent Drouet, Alain Haurie, Francesco Moresino, Jean-Philippe Vial, Marc Vielle, and Laurent Viguier, An Oracle Based Method to Compute a Coupled Equilibrium in a Model of International Climate Policy.
9. Socrates Kypreos, Stabilizing Global Temperature Change below Thresholds; Monte Carlo Analyses with MERGE.
10. Jürgen Scheffran, Adaptive Management of Energy Transitions in Long-Term Climate Change.